

DISPLAY ASSEMBLY WITH CONTRAST INVERSION  
INCLUDING TWO SUPERPOSED DISPLAY DEVICES

The present invention concerns a display assembly including two superposed display devices, a first display device farthest from the observer being surmounted by a second display device formed by a liquid crystal cell assembly and polarisers including control means to make visible either solely the information given by the  
5 second display device offering the possibility of inverting the contrast of all or part of said information, or the information given by the first display device.

The invention also concerns a timepiece provided with such a display assembly wherein the first display device is formed for example by the dial of the timepiece and the second display device is arranged between the crystal and the dial or merged with  
10 the crystal. The invention concerns more particularly such a timepiece wherein the dial cooperates with an analogue display.

According to another aspect of the invention, the information given by the first display device is permanently visible and that given by the second display device can be requested on demand to appear in a light colour on a dark background or  
15 conversely in a dark colour on a light background.

A display assembly including two superposed display devices able to take two different states wherein one of the display devices is visible to the exclusion of the other, is already known from European Patent No. 0 926 574 in the name of the Applicant. Such a display assembly in its application to a wristwatch is schematically  
20 shown in a diametral cross-section in Figure 1, the operating principle being given by Figures 2A and 2B.

The watch shown in Figure 1A, designated by the general reference 1, includes, in a conventional manner, a middle part 2, a back cover 3 and a crystal 20 together delimiting a case in the bottom part of which is arranged an electronic  
25 clockwork movement 4 powered by a battery 5. Movement 4 includes an electronic time-keeping circuit associated with a drive device (not shown), hour, minute and second hands 12, 14 and 16 moving above a dial 18 bearing hour symbols (not shown).

Hands 12, 14 and 16 and dial 18 constitute the first display device, which is of  
30 the analogue type in the example illustrated, and designated by the general reference 22.

This wristwatch 1 further includes a second display device of the digital type, designated by the general reference 24 and arranged between dial 18 and crystal 20. With reference again to Figures 2A and 2B, it can be seen that second display device  
35 24 is formed of a sandwich type structure including, moving from crystal 20 to dial 18,

an absorbent linear polariser 40, a liquid crystal display cell 26, an absorbent linear polariser 42 crossed with polariser 40, a liquid crystal optical valve 28 and a reflective polariser 44 crossed with polariser 42. The switching states of the cell and the valve of the second display device are controlled by a control unit 23 as a function of  
5 manipulations effected by means of at least one external control member 9.

Display cell 26 includes, in a conventional manner, a transparent front substrate 30, a back substrate 32 which is also transparent, and a sealing frame 34 forming spacing and closing means delimiting with substrates 30 and 32 a closed cavity containing liquid crystals 27. The opposite faces of substrates 30 and 32 include  
10 transparent electrodes respectively 36 and 38 made for example of ITO. In the example illustrated, back electrode 38 extends over the entire surface of substrate 32 and front electrode 36 is configured in segments or digits which can be addressed separately by means of control unit 23, the activated (ON) or non activated (OFF) state being symbolised by the contactor 6 in the diagram of Figure 2A and in the following  
15 diagrams. This cell 26 thus allows alphanumerical characters to be displayed by causing liquid crystals 27 to switch from a transparent state to an absorbent state, or vice versa depending upon the type of liquid crystals used. As will be understood hereinafter, in the application to a wristwatch where energy saving is of great importance, it will be preferable to use liquid crystals which give the cell a transparent  
20 state when no voltage is applied and an absorbent state when a voltage is applied.

Optical valve 28, containing liquid crystals 29 and having a contactor 8, has a comparable structure to that of cell 26 and differs from it only in that the two transparent electrodes totally cover the opposite faces of top substrate 31 and bottom substrate 33, so that valve 28 can switch from a totally transparent state to a totally  
25 absorbent state, or vice versa depending upon the type of liquid crystals used. For the reason indicated hereinbefore, liquid crystals 29 will preferably be selected to have a transparent state in the absence of voltage.

European Patent No. 0 926 574 only envisages two different operating states for the display assembly, as explained briefly with reference to Figures 2A and 2B  
30 annexed to the present patent application. Liquid crystals 27 and 29 which are respectively in cell 26 and valve 28 are of the positive anisotropy twisted nematic type.

In a first state shown in Figure 2A, in which cell 26 and valve 28 are not switched (OFF-OFF state), the natural non polarised light 46 is polarised vertically by first absorbent polariser 40 and designated by the general reference 48. Passing  
35 through cell 26, the axis of polarisation undergoes a rotation of 90°, so that the light passes through crossed polariser 42 without being modified. Passing then through valve 28, the axis of polarisation undergoes another rotation of 90° so that the

polarised light passes through reflective polariser 44 without being modified to reach dial 18 forming first display device 22.

The light follows the same path during its return travel, so that dial 18 is visible to an observer 50 placed in front of the display assembly.

5 In a second state shown in Figure 2B, the segments or digits 36 of the cell 26 are switched (ON state), and valve 28 is also switched (ON state) over the entire surface so that the vertically polarised light emerging from absorbent polariser 40 will have two different types of behaviour. In the zone in which cell 26 is not switched the polarised light follows the same path as previously as far as valve 28 which it passes  
10 through without undergoing another rotation so that, since its axis of polarisation is perpendicular to that of reflective polariser 44, it is totally reflected on its return travel concealing dial 18 from observer 50. In the zone of cell 26 in which segments 26 are addressed, the vertically polarised light 48 passes through cell 26 without modification, so that since its axis of polarisation is perpendicular to that of absorbent polariser 42, it  
15 is totally absorbed, the addressed segments appearing then in a dark colour on the light background.

According to a second embodiment described in European Patent No. 0926 574, the same visual effect is obtained with liquid crystals of the negative anisotropy twisted nematic type with a construction in which the three polarisers are parallel.

20 As can be seen, whatever the positive or negative anisotropy of the twisted nematic liquid crystals, the passage from an OFF-OFF switching configuration to an ON-ON switching configuration does not allow an inversion of the contrast to be obtained. In a known manner, such a contrast inversion could be obtained by means of inverse addressing, but at the cost of a demand for energy nine times greater than  
25 that which is necessary to address only 1/10 of the useful segments for the display, a solution which is unsatisfactory in a system where energy saving is of great importance.

Likewise, according to the teaching of the prior art, one could hope to obtain an inversion of the contrast by rotating a polariser by 90°, which would obviously cause  
30 great complication as regards a mechanical or manual drive system, especially for a display assembly of small dimensions, such as that able to be incorporated in a wristwatch.

In order to try to obtain an inversion of the contrast, it also seems natural, to avoid the aforementioned drawbacks, to examine the effect obtained with the device  
35 which has just been described by using a third switching possibility, namely the cell in the ON state and the valve in the OFF state, as shown in Figure 2C. Outside the switching zones of the segments of cell 26, the polarised light passes through valve 28

undergoing another rotation of 90°, so that it is polarised parallel to reflective polariser 44 through which it passes to be returned by the dial through an identical return path to observer. The second display is then shown in dark on the background of the dial, which must then necessarily be a light colour, but does not undergo any contrast inversion.

The second embodiment of European Patent No. 0 926 574 suggests acting on the relative orientation of the three polarisers. The appearances which it would be possible to observe with TN liquid crystals with positive anisotropy, for the two switching configurations able to generate an inversion of the contrast are summarized in the following table recalling those observed in Figures 2B and 2C.

Arrangement of polarisers P40 P42 P44	State		Display(s) able to be observed & contrast of 2nd display	Aspect according to Fig. No.
	cell C26	valve V28		
P ⊥ P ⊥ P	ON	ON	2nd D/L [P44]	2B
	ON	OFF	1st et 2nd D/L, if dial light	2C
P // P // P	ON	ON	1st et 2nd L/D, if dial light	3A
	ON	OFF	2nd L/D [P42]	3B
P // P ⊥ P	ON	ON	2nd L [P44] / D [P42]	4A
	ON	OFF	2nd L/D [P42], if dial light	4B
P ⊥ P // P	ON	ON	1st et 2nd D/L, if dial light	5A
	ON	OFF	2nd D/L [P44]	5B

Key: ⊥ crossed polarisers; // parallel polarisers

L/D light colour on dark background;

15 D/L dark colour on light background

The assembly shown in Figures 3A and 3B differs from the aforecited prior art in that the intermediate absorbent polariser 42 was rotated by 90° so that the three polarisers have parallel axes of polarisation. This configuration allows a second display in a light colour on a dark background to be obtained whatever the ON-ON or OFF-OFF switching state, i.e. reversed with respect to the preceding example, but without inversion for the display assembly as such when one passes from one switching state to another. In the assembly shown in Figures 4A and 4B, back reflective polariser 44 has also been made to undergo a rotation of 90° and it can be seen that the same visual effect as before is obtained, only with an inversion of the switching configuration. By making intermediate polariser 42 undergo a rotation of 90°

as shown in Figures 5A and 5B, one returns to the visual aspect of Figures 2A and 2B, again without obtaining an inversion of the contrast over the same display assembly.

The object of the present invention is thus to overcome the drawbacks of this prior art by providing a display assembly including two superposed display devices, allowing an inversion of the contrast to be obtained in one of the displays without increasing the energy requirement and without requiring a complex polariser drive mechanism.

The invention therefore concerns a display assembly with two superposed contrast inversion display devices including a first display device, a second active display device having a double structure, one structure being formed by a liquid crystal dot matrix display cell or by a digit liquid crystal display cell, said liquid crystals being confined in a space delimited by two transparent substrates and having two switching states (ON/OFF), and the other structure being formed by a liquid crystal optical valve, said liquid crystals being confined in a space delimited by two transparent substrates and having at least two switching states (ON-OFF), and control means allowing an appropriate voltage to be selectively applied to the cell and/or to all or part of the valve to cause them to switch from one state to another. This assembly is characterised in that a first polariser is arranged at the front of the display cell and in that a second polariser is arranged at the back of the valve so that, when the cell is switched (ON) to display at least one item of data, the total or partial switching of the valve, from one state to another, inverts the contrast of the data displayed from a light appearance to a dark appearance or vice versa, as a function of the light or dark shade of the first display device, and of the absorbent or reflective nature of the polariser, placed at the back of the second display device.

When the cell is not switched (OFF state), the display assembly can also have, as a function of the switching state (ON/OFF) of the optical valve, two other different aspects. According to one aspect, the second display is invisible, and the cell and the valve are transparent to allow the observer to see only the first display device. According to another aspect, the two displays device are made invisible by a mirror mask or a black mask depending on the reflective or absorbent nature of the back polariser.

According to another aspect of the invention, the valve can include at least two distinct reverse switching zones (ON/OFF), so that two types of data of the second display can be observed with an inversion of the contrast.

According to a further aspect of the invention, if there is no polariser between the display cell and the optical valve, it is possible to construct the second display

device with a transparent median substrate common to the display cell and the optical valve, thereby reducing the undesirable parallax effect.

The display assembly according to the invention thus allows a single assembly including two superposed display devices to have up to five different aspects simply by  
5 varying the switching mode of the display cell and the optical valve.

The invention also has the advantage of allowing the user to select the type of contrast best suited to the lighting of the place in which he is situated, namely a dark colour on a light background if there is not much light, or conversely a light colour on a dark background if there is a lot of light.

10 Other features and advantages of the present invention will appear more clearly upon reading the following embodiments and operating modes, with reference to the annexed drawings, in which:

- Figure 1A, already cited, is a cross-section of a wristwatch including a display assembly according to the prior art;

15 - Figure 1B is a particular embodiment of a display assembly according to the invention, incorporated in a wristwatch;

- Figures 2A and 2B, already cited, are schematic diagrams of the two operating modes disclosed in the prior art;

20 - Figure 2C, already cited, is a schematic diagram of another operating mode which may be envisaged with the display assembly of the prior art;

- Figures 3A, 3B, 4A, 4B, 5A and 5B, already cited, are schematic diagrams of modifications which may be made to the display assembly of the prior art;

- Figures 6, 6A to 6E are schematic diagrams of a first embodiment of a display assembly according to the invention;

25 - Figures 7, 7A to 7E are schematic diagrams of a variant of the first embodiment;

- Figures 8, 8A to 8E are schematic diagrams of a second embodiment of a display device according to the invention;

30 - Figures 9, 9A to 9E are schematic diagrams of a variant of the second embodiment; and

- Figures 10, 10A to 10E are schematic diagrams of another implementation mode of the invention.

The following description is made by way of example within the scope of an application of the invention to a timepiece such as a wristwatch of the type shown in  
35 Figure 1. It is to be understood that the invention is not limited to this application and that it could advantageously be used within the scope of any other application, such as

measuring or animation instruments for which an inversion of the contrast of all or part of the displayed data might be useful, aesthetically pleasing or surprising.

The actual construction of the two superposed display devices inside a wristwatch will not be described any further, given that, in its most general  
5 embodiment, it corresponds to what was already described with reference to Figure 1A, with the exception of intermediate polariser 42 which has been omitted.

In the case of an application to a wristwatch, the first display device will essentially display time related data and the second display device will display time related data complementary to such data or non time related data of sensor systems  
10 or processing systems, for example alphanumerical, integrated in the case of said timepiece.

In a particular embodiment shown in Figure 1B, it can be seen that crystal 20 can be omitted, provided of course that top transparent substrate 30 of cell 26 of the second display device 24 is given sufficient thickness. Given that the construction  
15 according to the invention no longer requires intermediate polariser 42, bottom transparent substrate 32 of cell 26 and top transparent substrate 31 of valve 28 can form a single transparent substrate 35 including on its outer faces transparent electrodes respectively for cell 26 and valve 28. Such an arrangement has the advantages of further reducing the parallax effect and increasing the brightness of the  
20 assembly given that a polariser, in its passive role (i.e. when the axis of the polarised light is parallel to the axis of polarisation of the polariser), normally involves a loss in brightness of 5 to 8% on each passage of polarised light.

With reference more particularly now to Figures 6, 6A to 6D, a display assembly according to the invention is shown, including a first display device 22 of the  
25 analogue type having a dark dial and a second display device 24, arranged between first device 22 and a crystal 20 on the side of an observer 50. This second device 24 is formed by a stack including a front absorbent polariser 40 oriented towards the crystal, a twisted nematic liquid crystal cell 26 with positive anisotropy, whose segments can be switched from one state to another (ON/OFF) by means of a switch 6, an optical  
30 valve 28 having the same liquid crystals as those of cell 26, or another liquid crystal with positive dielectric anisotropy able to be switched from one state to another (ON/OFF) by means of a switch 8 and a reflective polariser 44 crossed with polariser 40.

In Figure 6A, which shows on the left a cross-section of the assembly shown in  
35 Figure 6, and on the right the appearance of the display assembly visible to observer 50, cell 26 and valve 28 are not switched, the OFF-OFF configuration which will be designated hereinafter by the letter A. The polarised light 48 undergoes a first rotation

of 90° through cell 26 and a second rotation of 90° through valve 28 so that its axis of polarisation is perpendicular to that of reflective polariser 44: the light is then reflected following an identical return path and first display 22 is hidden by a mirror mask formed by polariser 44 so that no data is displayed.

5           In Figure 6B, cell 26 is switched (ON) and valve 28 is not switched (OFF), this configuration being designated hereinafter by the letter B. In the zones which do not include addressed segments 36, polarised light 48 follows the same travel as before and a mirrored background is obtained. In the zones where the segments are addressed, represented in the Figure by the central zone, polarised light 48 passes  
10 through cell 26 without modification, undergoes a rotation of 90° passing through valve 28, so that since its axis of polarisation is parallel to that of reflective polariser 44, it passes through it without modification to be reflected by dial 18 and to follow an identical return path. The observer thus sees portions of the dark dial through these transparent windows, so that the data provided by cell 26 is shown in a dark colour on  
15 a light background with a mirror effect.

          In Figure 6C, cell 26 is not switched (OFF) and valve 28 is switched (ON), a configuration which will be designated hereinafter by the letter C. All of polarised light 48 passes through cell 26 undergoing a rotation of 90°, then passes through valve 28 without modification, so that by having its axis of polarisation parallel to that of the  
20 reflective polariser, it passes through it to hit the dial and be reflected by an identical return path to the outward travel: the observer thus only sees the first display device associated with dial 18.

          In Figure 6D, the segments of cell 26 and valve 28 are switched (ON-ON), a configuration which will be designated hereinafter by the letter D. The polarised light  
25 rays which pass through the assembly in zones which do not have addressed segments allow portions of the dial to be seen, as shown in Figure 6C, i.e. they provide a dark background. Conversely, in the zones where the segments are addressed, polarised light 48 passes through cell 26 and valve 28 without modification, and arrives at the reflective polariser with a direction of polarisation which is  
30 perpendicular to that of said polariser, so that it is reflected following a return path causing the data supplied by the second display to appear in a light colour on a dark background. As is seen passing from switching configuration B to switching configuration D, an inversion of the contrast from dark to light is obtained in the displayed data.

35           Figure 6E shows a switching configuration, designated hereinafter by the letter E, in which cell 26 is switched (ON) and the valve includes a switched rectangular top surface (ON), causing part of the data to appear in this zone in a light colour on a dark



background, and the rest of the surface in the non switched state (OFF) causing the other part of the data to appear in a dark colour on a light background. This switching configuration which allows an inversion of the contrast to be obtained at the same time, for example allows one to differentiate between two varieties of complementary data or data of a different nature.

As can be seen, the different aspects of the display assembly according to the invention, and in particular the contrast inversions, are obtained very simply by switching configurations resulting from positions of switches 6, 8, themselves controlled by control unit 23 and responding to manipulations effected on at least one external control button 9, it being specified that the designer is free to select only certain switching configurations.

In the variant shown in Figures 7, 7A to 7E, the construction differs from the preceding one in that the two polarisers 40, 44 are parallel, which has the effect, with respect to Figures 6, 6A to 6C, of permuting the switching configurations, on the one hand between the mirror mask and the first display device only, on the other hand between the two contrast inversion states. In configuration A, the first display device is permanently visible, without consuming any energy, while masking by a mirror mask is obtained with configuration C. In configuration B, the second display appears in a light colour on a dark background while the inversion of the contrast is obtained with configuration D. It will be observed that the appearance of the display assembly with configuration E is naturally unchanged.

With reference now to the embodiment shown in Figures 8, 8A to 8E, it can be seen that the construction proposed arises from the same principle as before, but differs therefrom in that dial 18 of the first display device is in a light colour and back polariser 44 is an absorbent linear polariser, crossed with front polariser 40 in this embodiment. In switching configuration A (OFF-OFF) shown in Figures 8 and 8A, polarised light 48 undergoes a rotation of  $90^\circ$  passing through cell 26, then a second rotation of  $90^\circ$  passing through valve 28 so that it hits polariser 44 with its axis of polarisation perpendicular to that of absorbent polariser 44: it is thus totally absorbed masking the first display with a black mask. By following the travel of the light rays as was explained in the preceding examples, it can be seen that configuration B allows just the second display device to be in a light colour on a dark background, configuration C just the first display device, configuration D allows the first display device to have an inversion of the contrast with respect to that obtained with configuration B, and configuration E allows two parts of the data supplied by the second display device to be simultaneously displayed with an inversion of the contrast.

In the variant shown in Figures 9, 9A to 9E, the construction differs from that which has just been described with reference to Figures 8, 8A to 8D, in that back polariser 44 is parallel to the front polariser, generating the same effect as explained for the variant described in Figure 7 with respect to Figure 6. Thus, in configuration A, observer 50 sees only the first display device, in configuration B, he sees the second display device in a dark colour on a light background, in configuration C, he sees only a black mask, in configuration D he sees only the second display device in a light colour on a dark background, i.e. with an inversion of the contrast with respect to that observed with configuration B, and in configuration E, he sees two parts of the data supplied by the second display device with contrast inversions.

In the examples which have just been described with reference to Figures 6 to 6E, liquid crystals 27, 29 filling cell 26 and valve 28 both had positive anisotropy. If cell 26 and valve 28 are now filled with liquid crystals with negative anisotropy with a homeotropic alignment with a potential rotation of  $90^\circ$ , exactly the same visual appearance will be obtained with exactly the same switching configurations. If there is the same construction as in Figure 6, in a switching configuration A (OFF-OFF), it can be seen that the vertically polarised light 48 passes through cell 36 and valve 28 without modification to hit reflective polariser 44 perpendicular to its axis of polarisation and that it is reflected following an identical return path: the observer then sees a mirrored background as was the case shown in Figure 6A. The same will be true with the other switching configurations which will allow the contrast inversion observed between Figures 6B and 6D to be obtained, as well as with the other constructions corresponding to Figures 7 to 9.

Figures 10 and 10A to 10E show a display assembly according to the invention the construction of which is the same as that of Figure 6, but wherein cell 26 has been filled with liquid crystals 27 of the twisted nematic type with negative anisotropy and valve 28 with liquid crystals 29 of the twisted nematic type with positive anisotropy. In switching configuration A (OFF-OFF), it can be seen in Figure 10A that polarised light 48 undergoes a rotation of  $90^\circ$  passing through cell 26, that its orientation is not modified passing through valve 28, and since its axis of polarisation is parallel to that of reflective polariser 44, passes through it while being reflected by the dial to follow an identical return path. Observer 50 thus sees the first display device as shown in Figure 10A. Following the travel of the polarised light in the same way, observer 50 sees the second display device in a light colour on a dark background in switching configuration B (Figure 10B), a mirrored background in switching configuration C (Figure 10C), the second display device with a contrast inversion in a dark colour on a light background in switching configuration D (Figure 10D) and a double contrast inversion in switching

configuration E (Figure 10E). It is to be observed then that with the same switching configurations, the same visual aspects are obtained as can be observed in Figures 7A to 7E. If one now uses, with the cell and valve filled as hereinbefore, the construction corresponding to Figure 7, it is easy to see that conversely, still with the identical switching configurations, the visual appearance shown in Figures 6A to 6E is obtained. Again, still with the cell and valve filled in the same way, the construction of Figure 8 will give the visual appearances shown in Figures 9A to 9E, and conversely the construction of Figure 9 will give the visual appearances shown in Figures 8A to 8E. It is to be noted finally that by permuting the order of filling of the liquid crystals in the cell, and the valve, the appearances which have just been described with reference to Figures 10 and following are unchanged.

Thus, whatever the embodiments and variants, the display assembly according to the invention always allows an inversion of the contrast to be obtained in the data supplied by the second display device, simply by taking care to associate a first display device having a dark dial with a second display device having a reflective back polariser, and conversely a first display device having a light coloured dial with a second display device having an absorbent back polariser. It is clear that the notion of "light" or "dark" colouring for the dial depends on the level of contrast which one wishes to obtain.

In the examples which have just been described, the first display device was shown, by way of example, as being of the analogue type. Without departing from the scope of the invention, said first display device may also be of the digital type or mixed analogue-digital type, and further include at least one decorative element. Likewise, without departing from the scope of the present invention, the digital part of the first display device may have a comparable structure to that of the second display device thereby increasing the number of effects able to be obtained with a single display assembly depending on appropriate configurations of the switched or non switched state of the two cells and two valves.

Without departing from the scope of the invention, it is possible to fill cell 26 and valve 28 with compositions acting on the polarised light different from the liquid crystal family which has just been described, allowing for example either the second display device to have a higher multiplexing level, or a different control voltage to be obtained for cell 26 and valve 28 so as to lead to a simplification of control circuit 23, or to provide a memory effect. By way of non limiting illustrative example, twisted nematic (TN) liquid crystals can be used for display cell 26 and in plane switching (IPS) or cholesteric texture (CT) liquid crystals for valve 28, which provides a memory effect.

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